# DAMAGE DETECTION USING THE HOLDER EXPONENT

Mackinac Bridge, MI, USA (www.worldstart.com)

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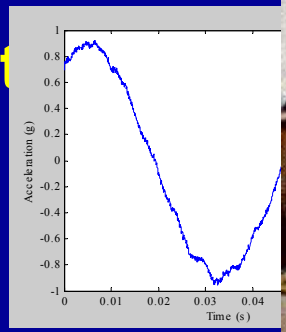
Los Alamos NATIONAL LABORATORY

# Overview

- Motivation
- Background and previous
- Our endeavor
- Results and next





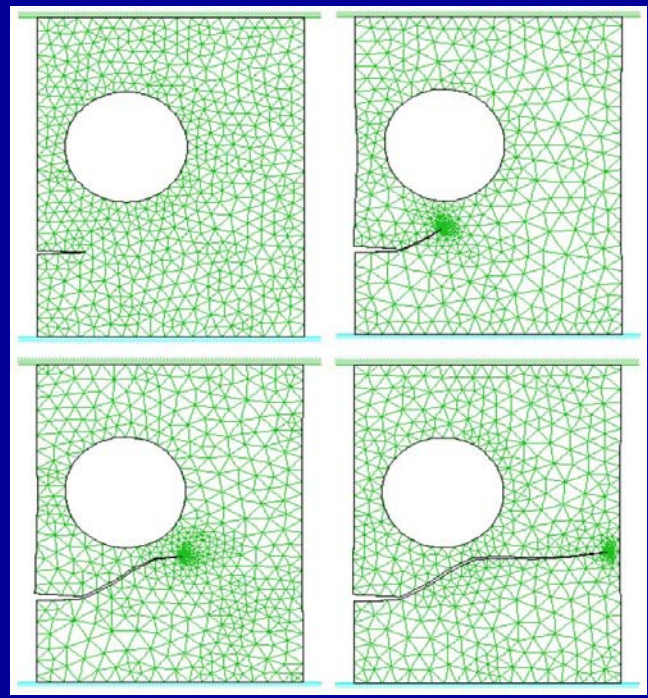
Courtesy of the Navy Research Lab

# Damage introduces non-linearities in a structural system

Crack initiation and propagation

Bolt pretension loss

Loose part “rattle”



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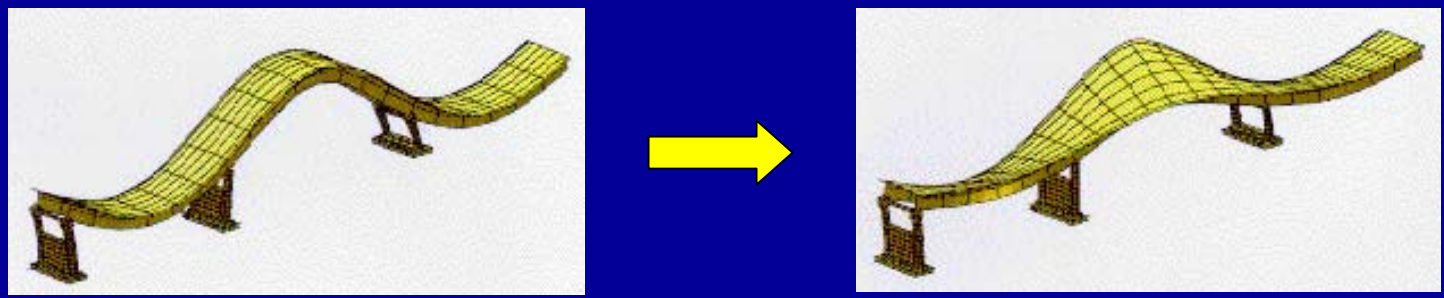
# Current detection methods characterize changes in linear models of the structure

- Modal shapes and parameters



www.lanl.gov

- Autoregressive correlation coefficients

# However, these methods are not foolproof

- Modal analysis methods only detect global changes
- Autoregressive models do not take advantage of non-linearities

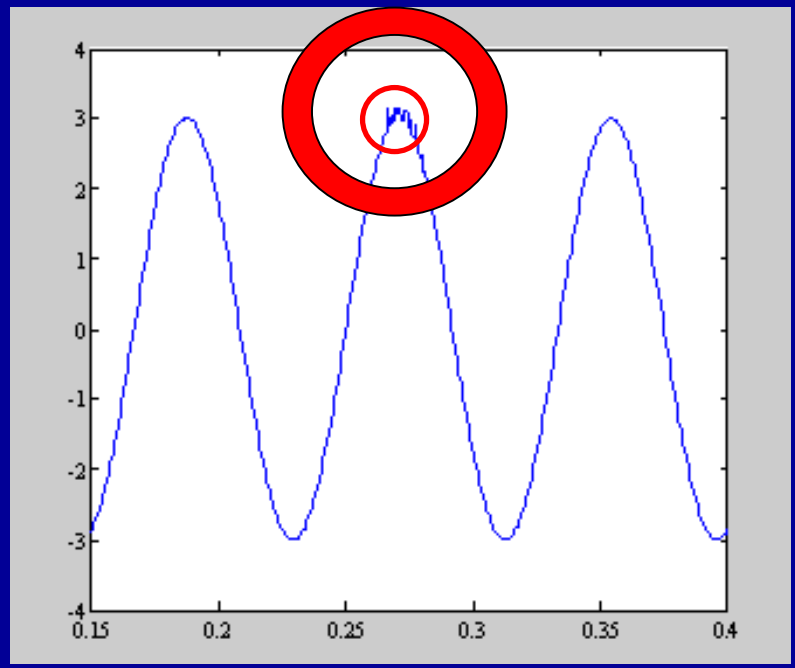
Monitoring of structural health should involve pinpointing damage:

- In time
- In space

# A damage detection method using a feature known as the Holder Exponent is explored

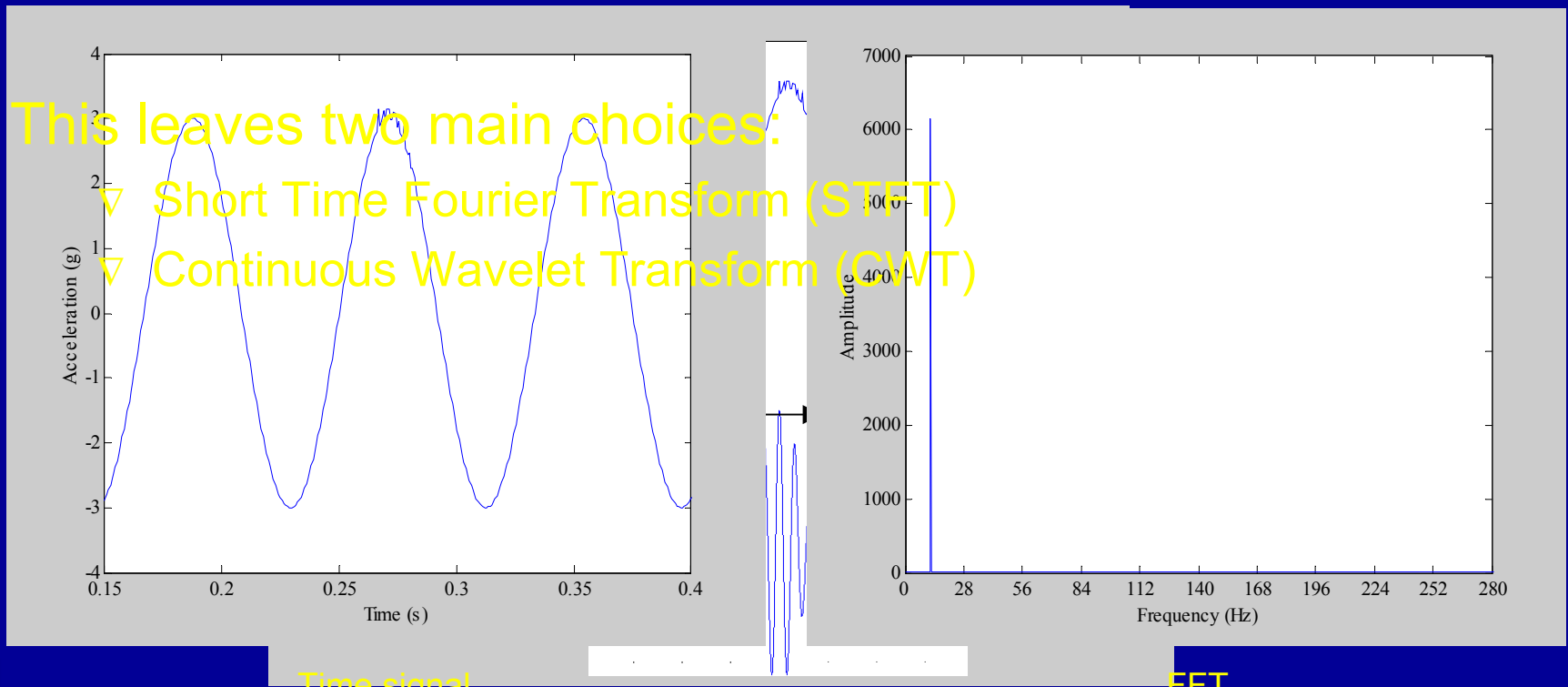
## How?

- Measures time signal regularity
- Extracts instantaneous high frequency content




# Calculation of the Holder Exponent relies on time-frequency analysis methods

## Fast Fourier Transform (FFT) shortcomings

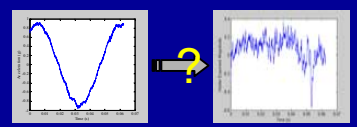



This leaves two main choices:

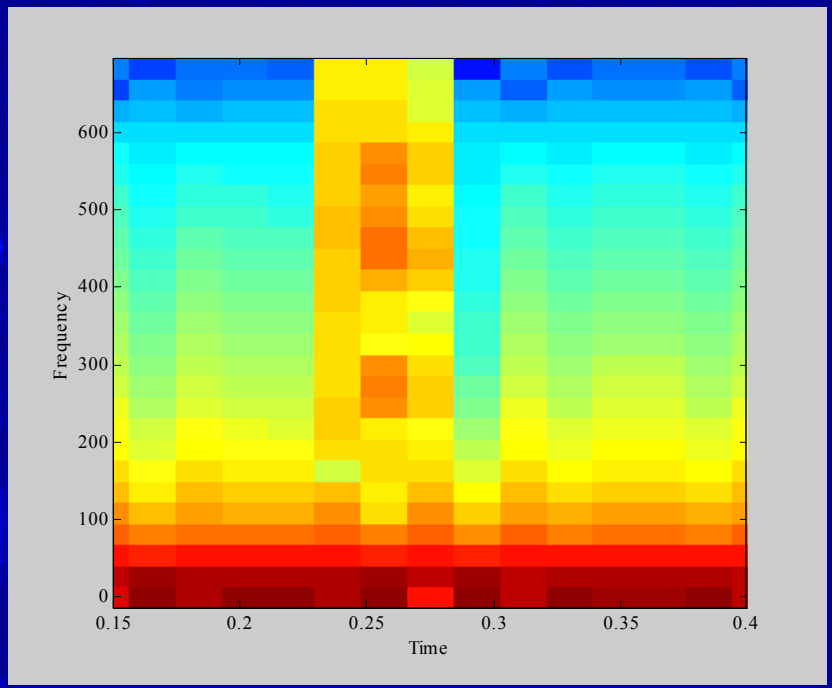
- Short Time Fourier Transform (STFT)
- Continuous Wavelet Transform (CWT)

STFT/CWT Concept

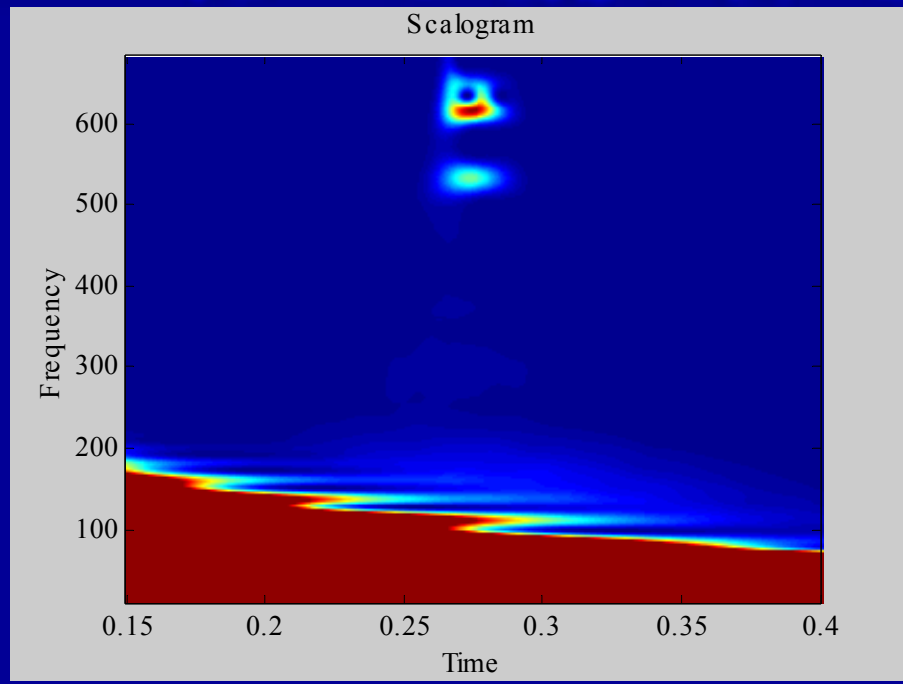




# The important difference between the STFT and the CWT lies in resolution



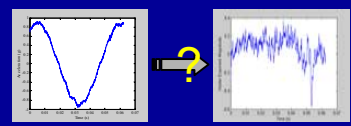

STFT



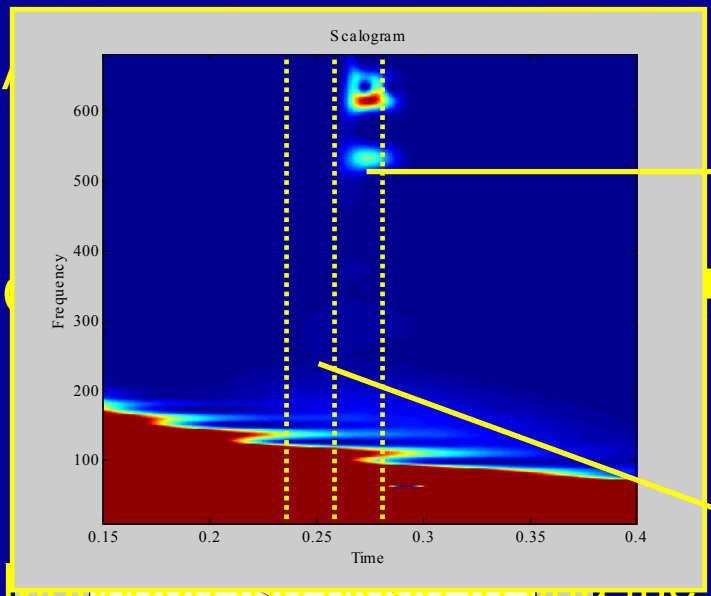

CWT

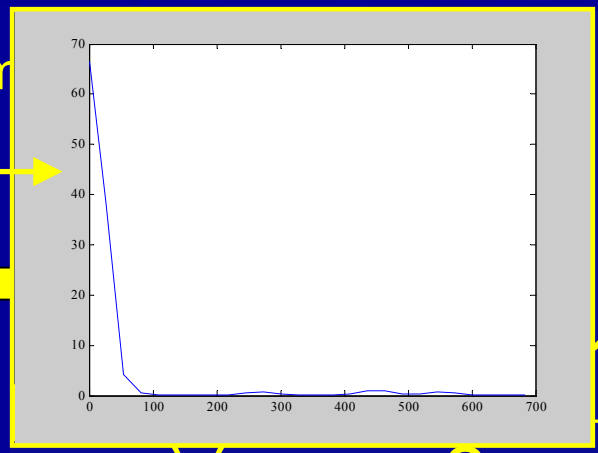
The excellent time resolution at high frequencies is key

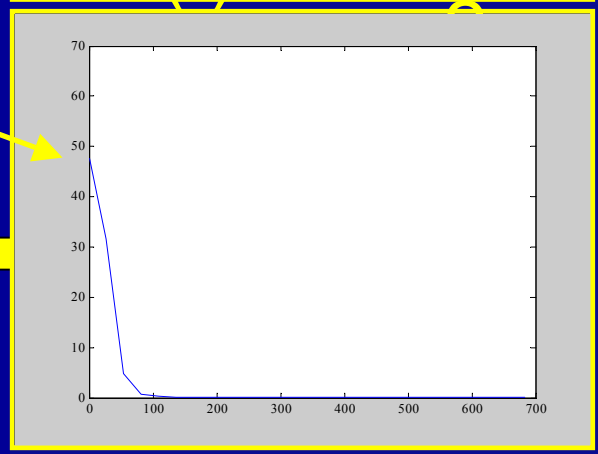


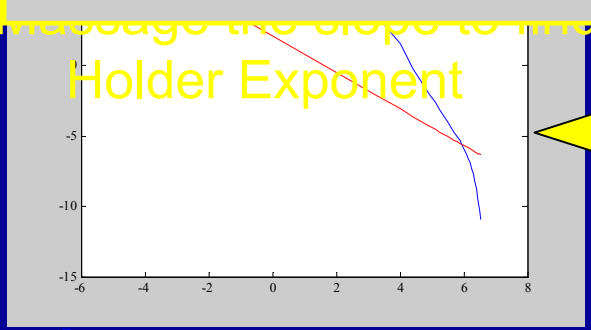


# The Holder Exponent can be computed directly from the CWT

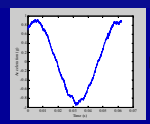


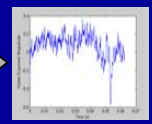




Holder Exponent





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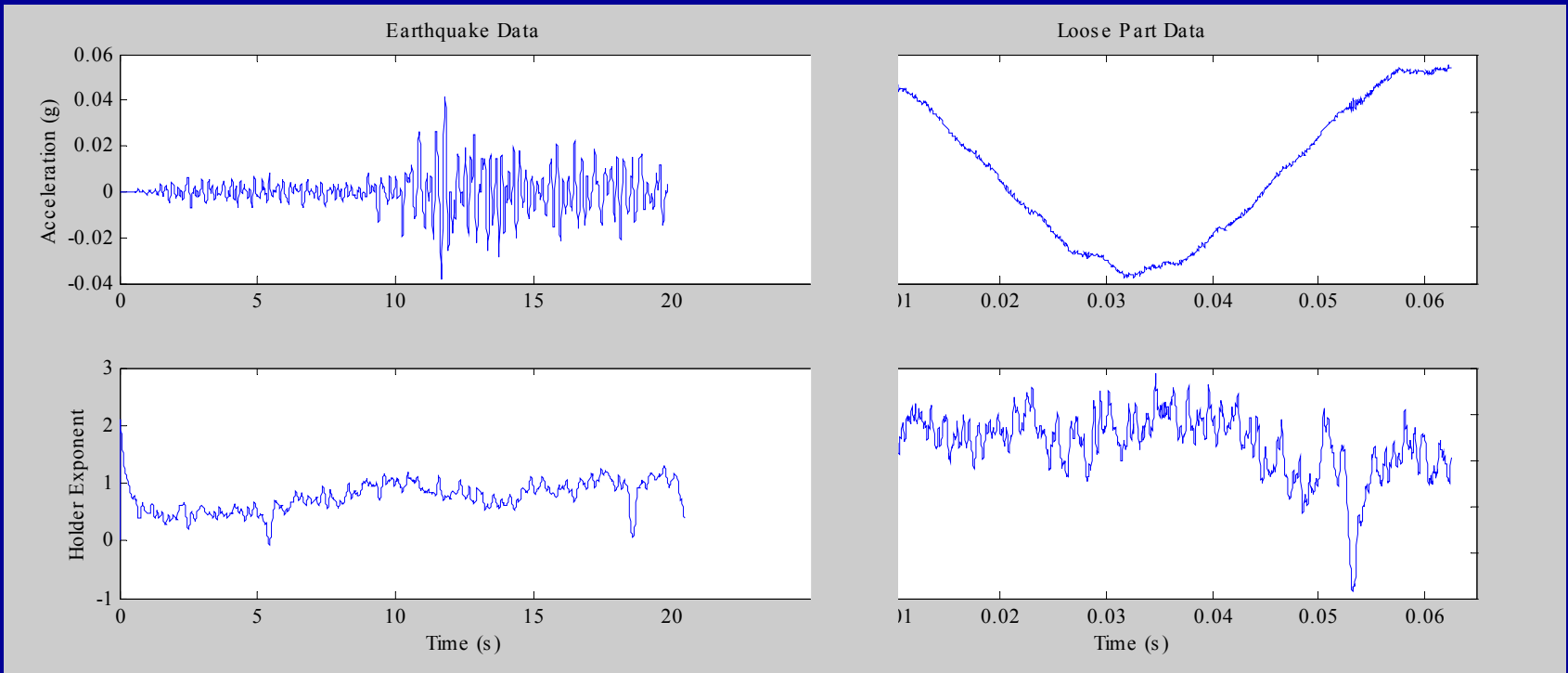
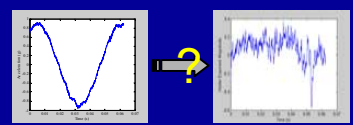
# Robertson and Farrar first explored the capability of the Holder Exponent

## Doctored earthquake data

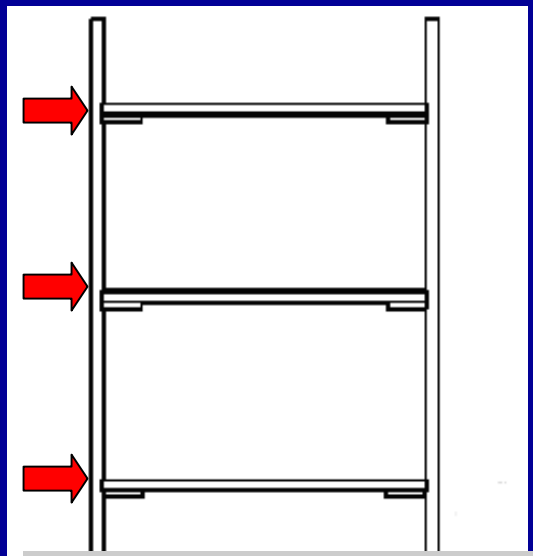
## Loose part rattle

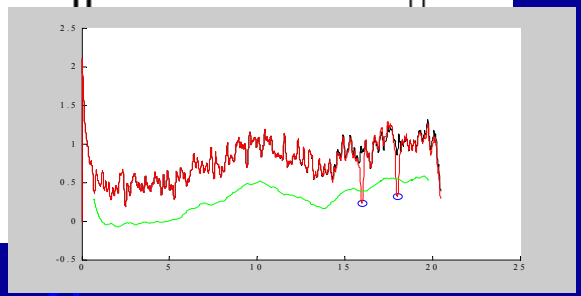




# The effectiveness of the Holder Exponent is explored by testing physical models



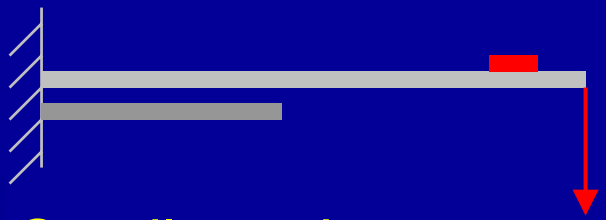



Applicability to “real world” structures

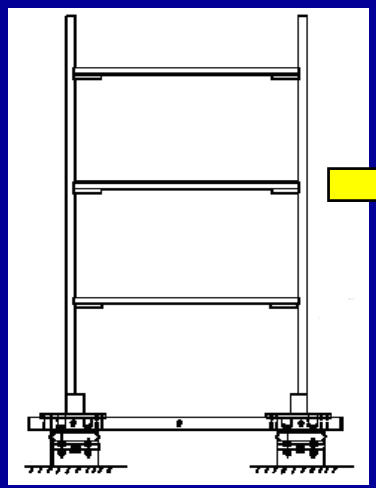
Sensitivity to instrument locations

Automating the detection process with a Statistical Process Control (SPC)

# The tested structures modeled different forms of damage



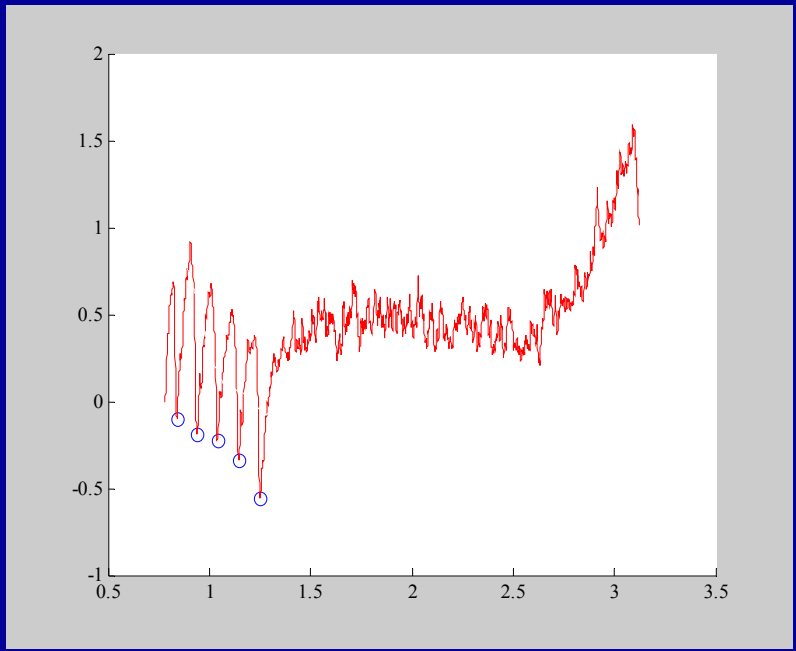
Cantilever beam

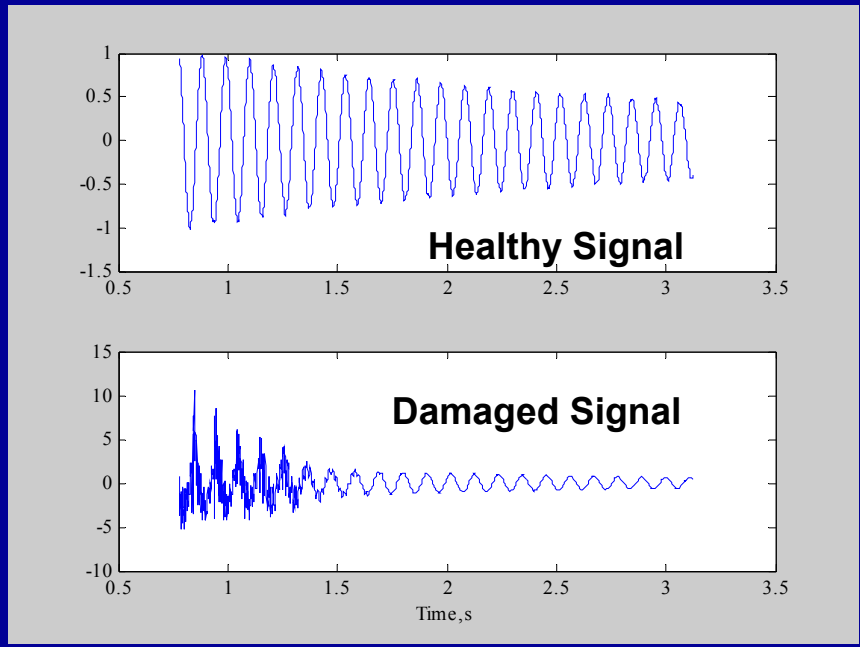


Three-story structure

5 DOF system

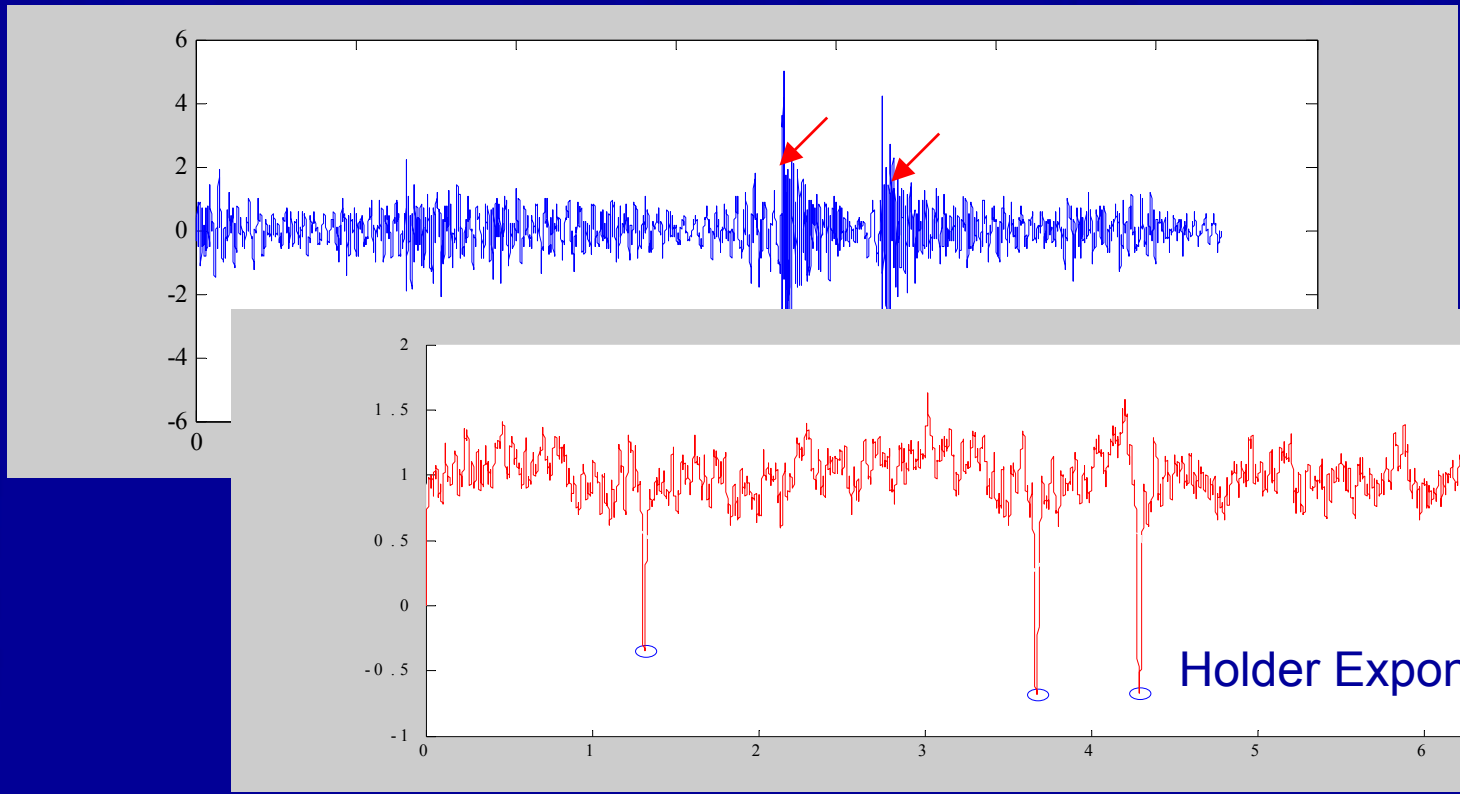
# Results from the cantilever beam showed the Holder Exponent was sensitive to damage




However, obvious events do not really need detection methods

# The Holder Exponent detected damage in the 5 DOF, but some features were obvious in the time signal




Magnitudes and occurrences of the impacts were difficult to control

# The three-story structure produced varying results based on the input

The Holder Exponent is effective for periodic inputs

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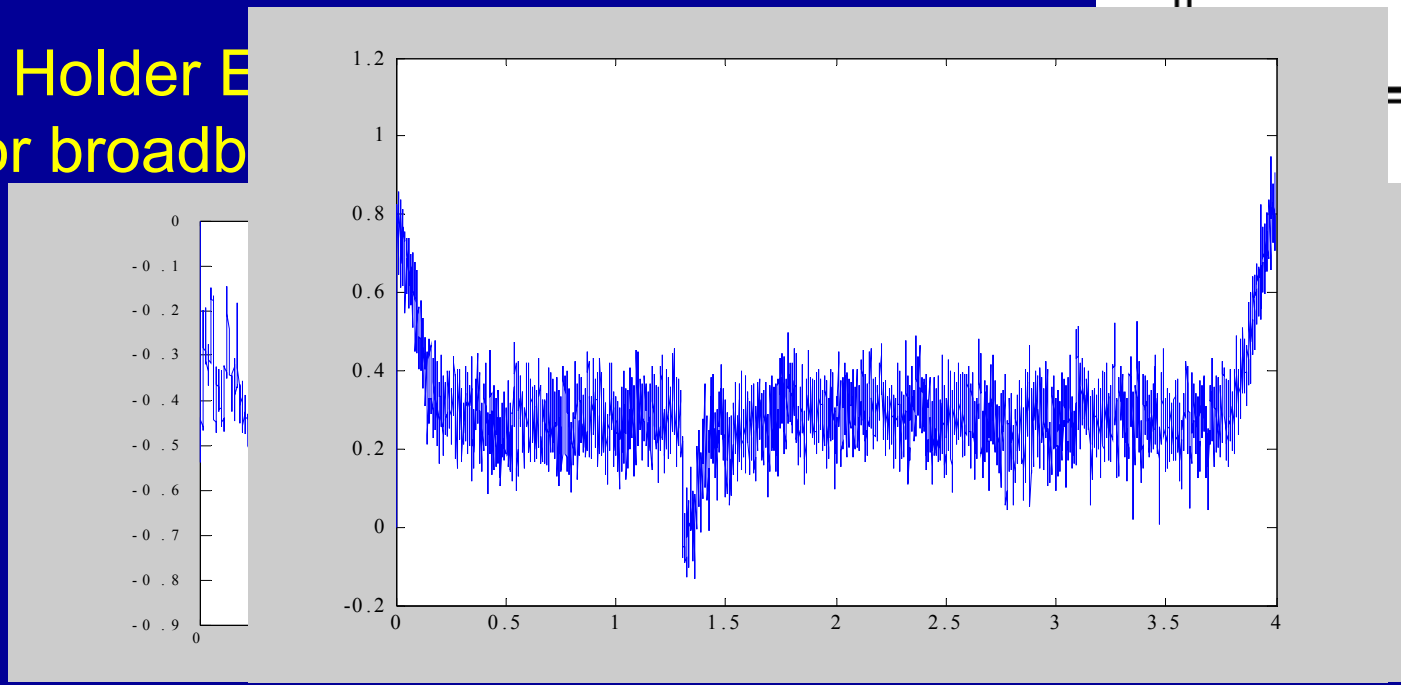
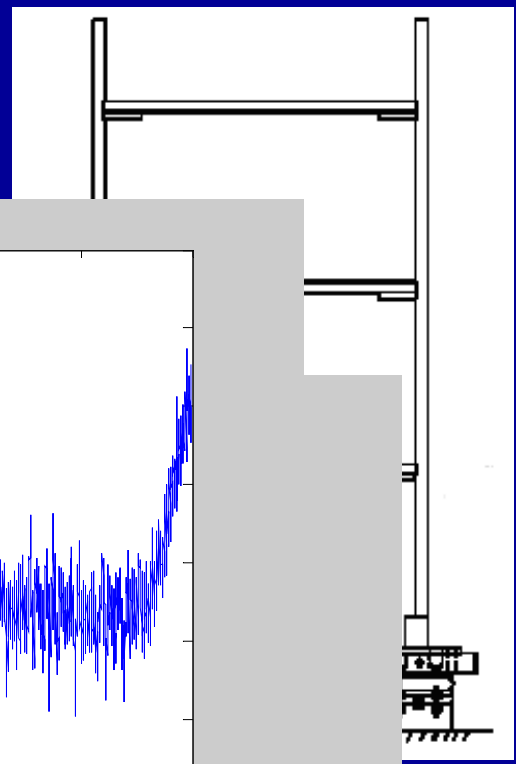
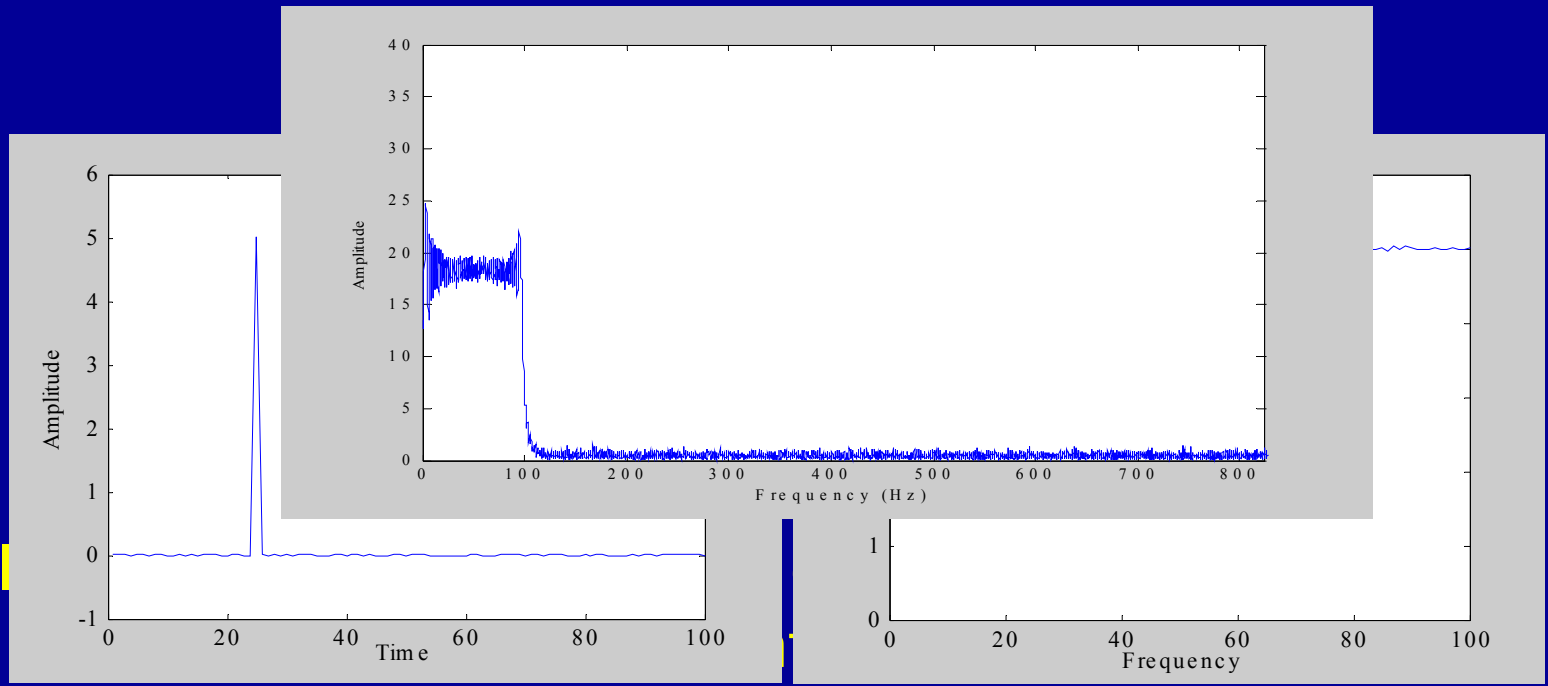


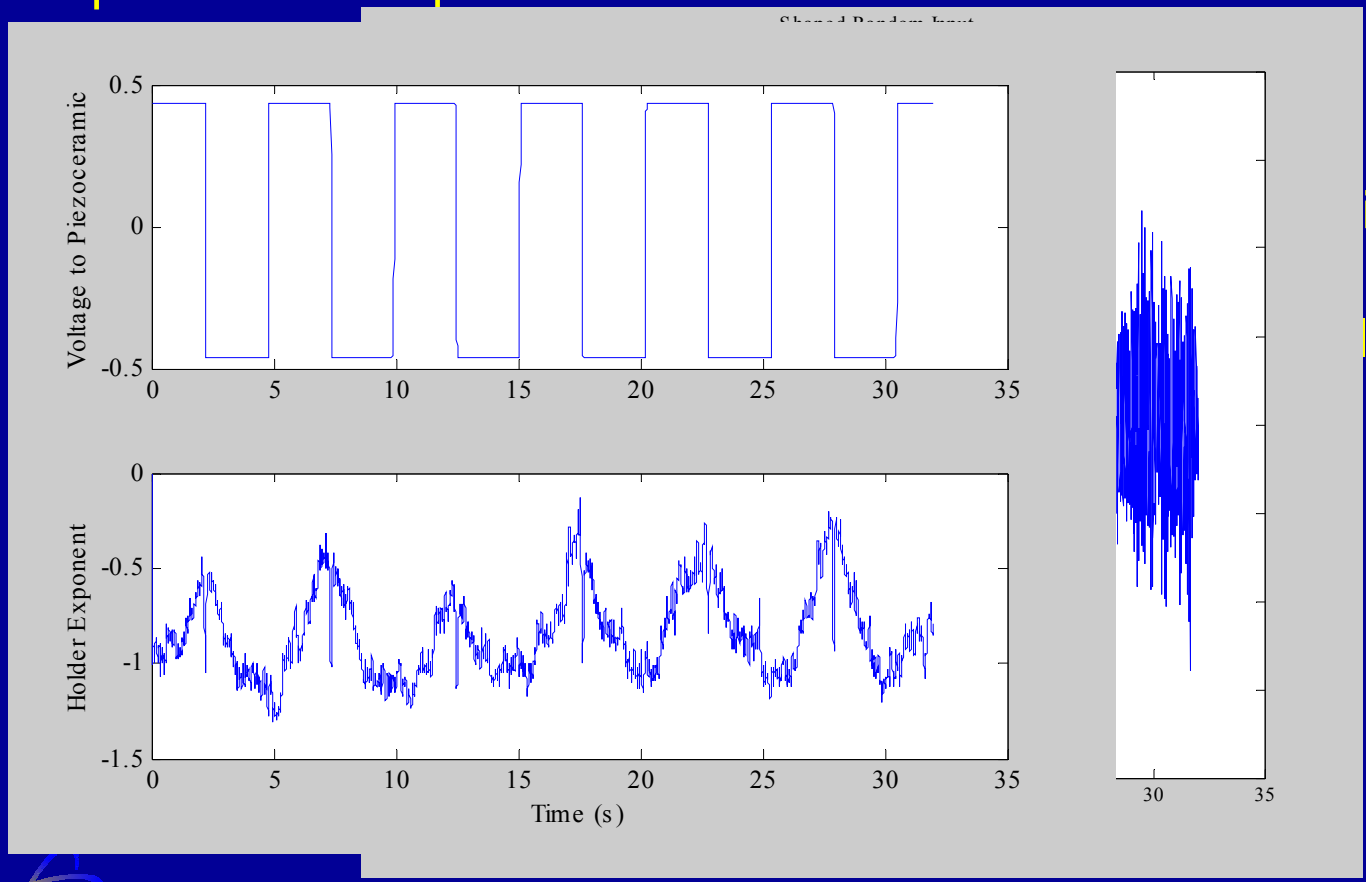
# A return to the fundamentals illuminated why random inputs were not giving favorable results

Frequency content of impulse is broadband




# Armed with this insight, the three-story structure was revisited

Shaped random input



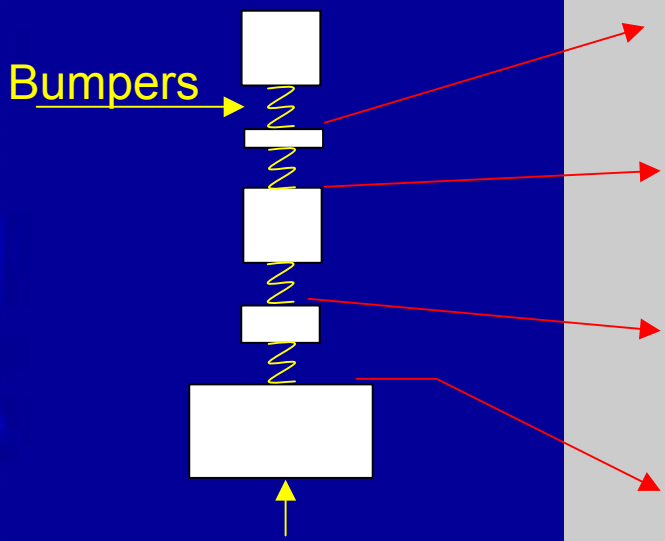

ing results for
world
lications

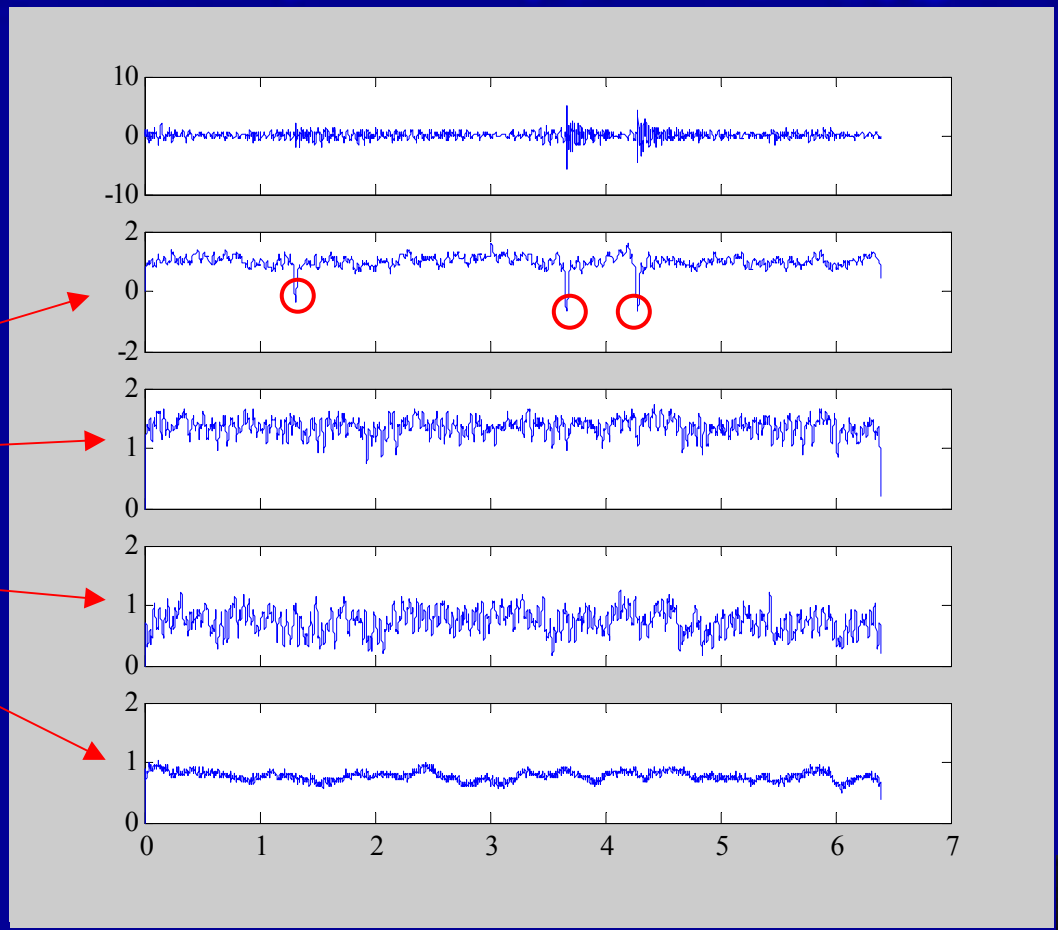


# Subsequently, the sensitivity to proximity was explored

## 5-DOF system:

- Limited sensitivity

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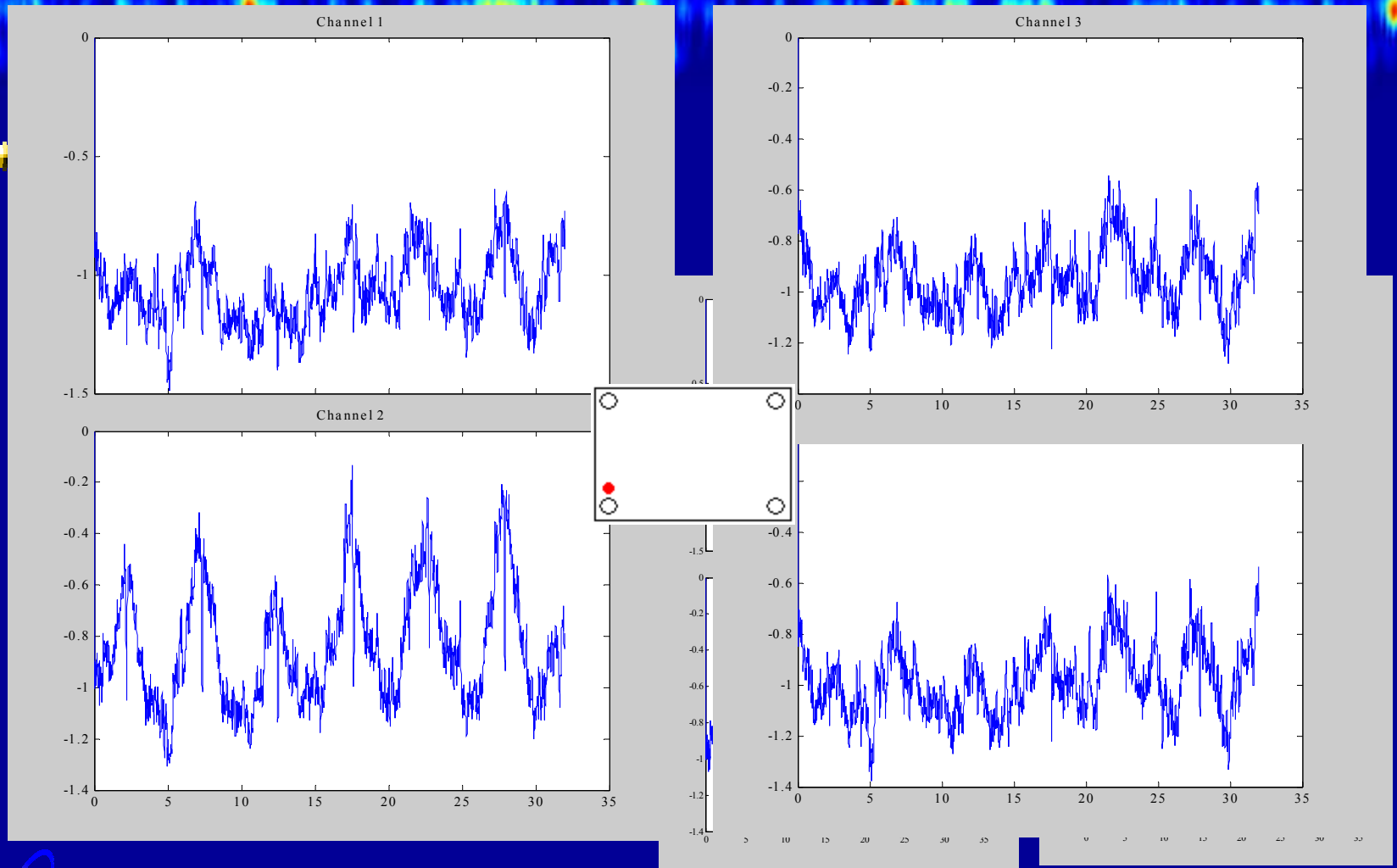
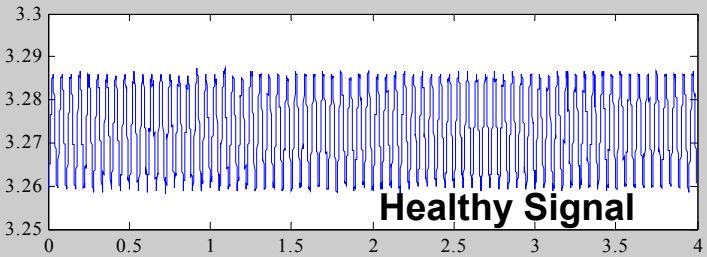
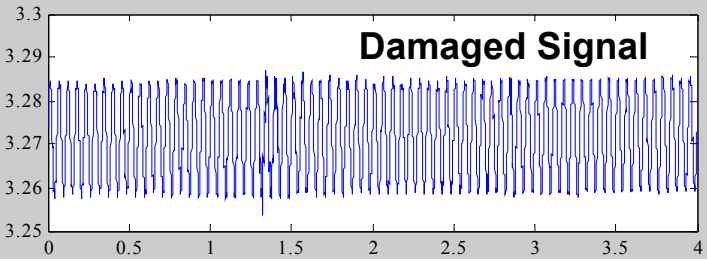
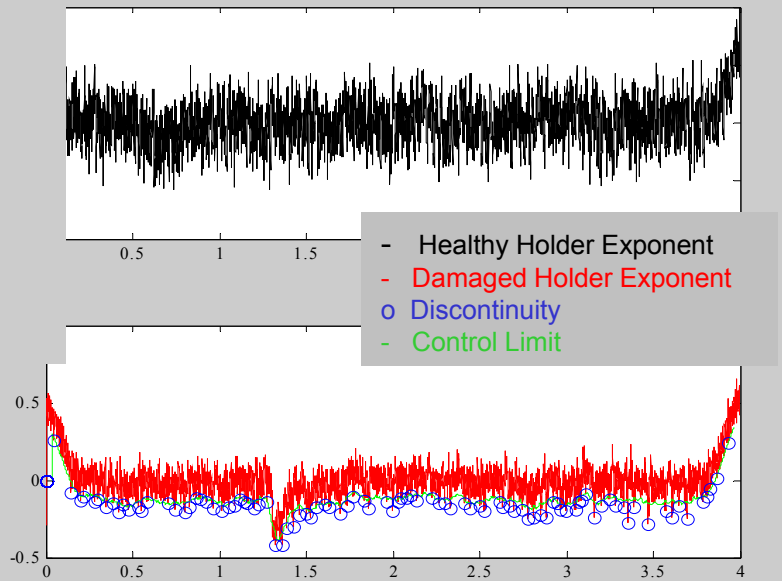


# A SPC was developed to assess the feasibility of automating the detection scheme



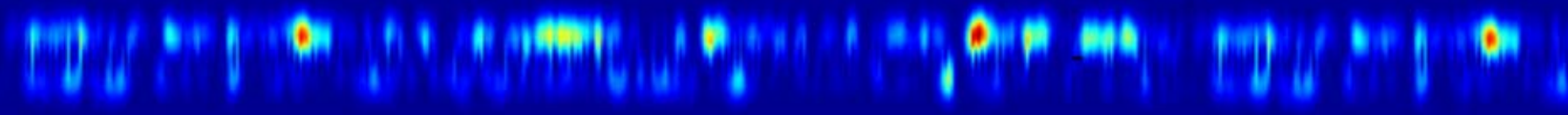




Establishment of control limits




Best results when healthy data is used

# Significant discoveries were made with regards to the usefulness of the Holder Exponent

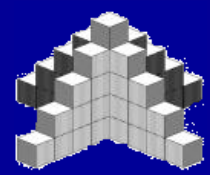


- Frequency content of the input is important
- Information from damage events is attenuated
- Automating the detection process seems to hold promise

# The applicability of the Holder Exponent could be further characterized

- Sensitivity to damage level
- Quantify proximity sensitivity for more systems





# Acknowledgments


- Special thanks to Jeanette Wait for procedural and data extraction help
- Thanks to Amy Robertson and Hoon Sohn for aiding in our understanding of the fundamentals
- Thanks to the Engineering Science and Applications Division at the Los Alamos National Laboratory and the Dept. of Energy's Education Programs Office for funding
- Thanks to The Mathworks, Inc. for generously donating numerical analysis software

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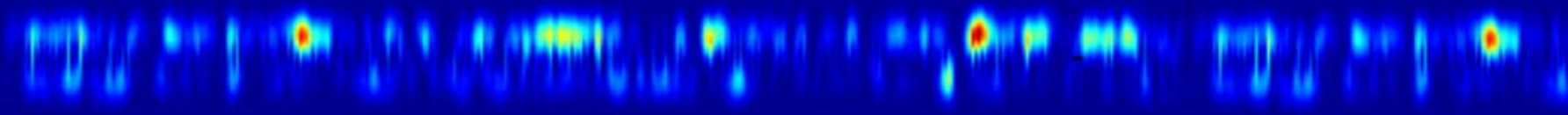

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QUESTIONS?